GENDE: GENetic DEsign

Best Products Evolve According to Users Feedback

Andrea Vitaletti

Abstract GENDE (http://www.gende.it) is a tool to allow designers, but also common people, to automatically design new products that evolve according to the principles of Genetic Algorithms (GAs). The selection of the products that will actually take part to the evolutionary process, relies on crowdsourcing mechanisms: only the most appreciated products survive. In the era of 3D-printing, GENDE can pave the way to a completely new class of mass products in which personalization become intrinsic to the design process and is driven by common users rather than being confined in the later stages of production and in the hands of professional designers. While GENDE has been originally thought as an automatic design tool, its unique process that involves users from the beginning of the design, can also be used as a powerful marketing tool.

Keywords Interactive design · Genetic algorithms · Crowd sourcing · Participatory design

1 Introduction

GENDE (http://www.gende.it) is a tool to allow designers, but also common people, to automatically design new products that evolve according to the principles of Genetic Algorithms (GAs) (Mitchell 1998).

The process starts with the encoding of the distinctive features of the desired product into a digital chromosome. This allows the generation of an initial random population of products. Such population is evaluated by end-users employing classical online social feedback mechanisms (e.g. Facebook like). The selection of best individuals, relies on crowdsourcing mechanisms, and it is implemented by a fitness function computed over the users feedback on the current population of products. Such best individuals survive and generate a new generation of individuals that

A. Vitaletti (✉)
University of Rome "La Sapienza", DIAG, via Ariosto 25, 00185 Rome, Italy
e-mail: vitaletti@diag.uniroma1.it

R. Rinaldi and R. Bandinelli (eds.), *Business Models and ICT Technologies for the Fashion Supply Chain*, Lecture Notes in Electrical Engineering 413,
DOI 10.1007/978-3-319-48511-9_9

share many of the characteristics of its parents, but can also introduce some mutation. This process is iterated generation after generation until best individuals are positively evaluated by the vast majority of users; the outcomes of the process are 3D models of the best products ready for small-scale series (e.g. 3D print).

Similar ideas have been investigated in generative design (Hartmut et al. 2012; Tedeschi 2014), but mostly in the domain of digital products and without taking fully advantage of GAs. Genetic algorithms have been investigated to generate pictures (Grow your own picture: 2016) or music (Genetic music project. 2016), but only marginally for the collaborative design of physical products (Kram and Weisshaar 2003; Hamda and Schoenauer 2004) and fashion design (Kim and Cho 2005). In the era of 3D-printing, GENDE can pave the way to a completely new class of mass products in which personalization happens from the design process and is driven by common users rather than being confined in the later stages of production and in the hands of professional designers. However, more realistically, in the shorter term GENDE will be employed by product companies to design new products taking advantage of the unique genetic process that naturally embodies marketing aspects (i.e. users feedback) into the design process. In the current stage, GENDE is a proof-of-concept, and still needs some development to be market ready.

Structure of the paper. In Sect. 2 we introduce GENDE concept and we give a short overview on Genetic Algorithms (GAs) principles. In Sect. 3 we discuss the related work and we review some papers that support the use of GENDE not only as a design tool, but also as a marketing tool. In Sect. 4 we present a proof-of-concept of a minimalistic lamp designed by GENDE and finally in Sect. 5, we discuss the main challenges we have to face to make GENDE a real product.

2 GENDE Concept

GENDE is a tool that employs Genetic Algorithms (GAs) for the design of new products. A genetic algorithm (GA), is a search heuristic that mimics the mechanisms of natural selection. In GAs, a population of candidate solutions (named individuals) to an optimization problem evolve toward "better" solutions. Each candidate solution has a set of features that are encoded in a *digital chromosome*. In the example in Fig. 1, the width and length of an eyewear (i.e. an individual) are encoded in the chromosome. A random population of individuals is initially generated. The population evolves in an iterative process generation after generation, as shown in the example in Fig. 2. In each generation, the fitness of every individual in the population is evaluated by a *fitness function*, that in case of GENDE evaluates users' appreciation for the individual, and only the "best" individuals survive and contribute to populate the next generation. In particular, the genome of the best individuals of the current generation are recombined and possibly randomly mutated to form the new generation. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population.

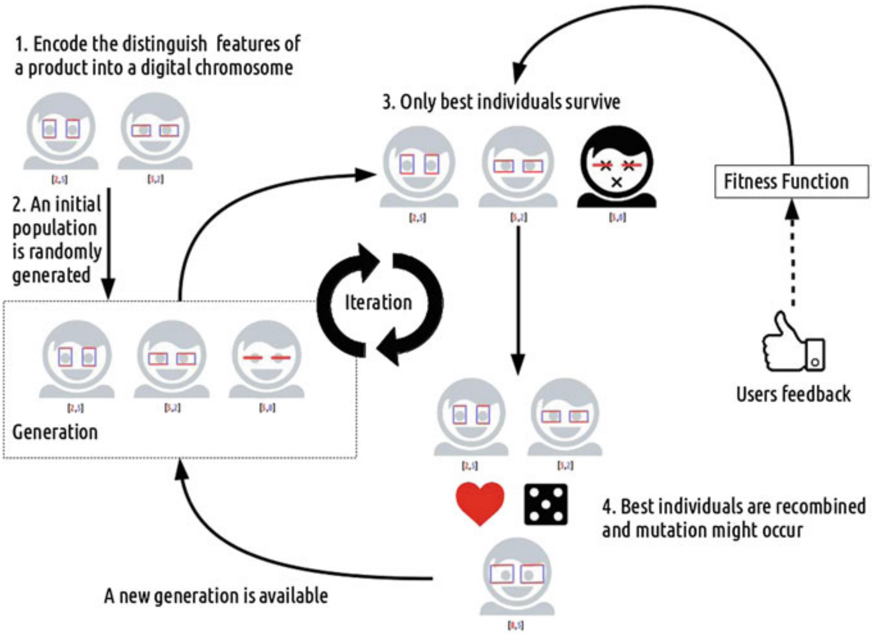


Fig. 1 An schema of the evolution of genetic algorithms

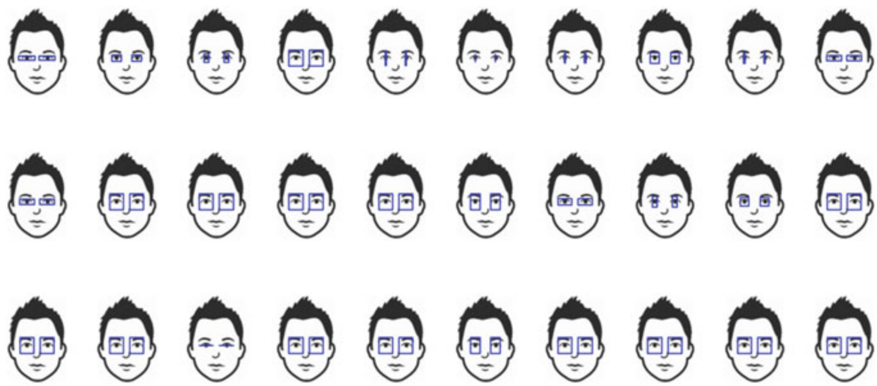


Fig. 2 Three generations of eyewears. In this simple example the fitness function maximizes the size of the eyewear

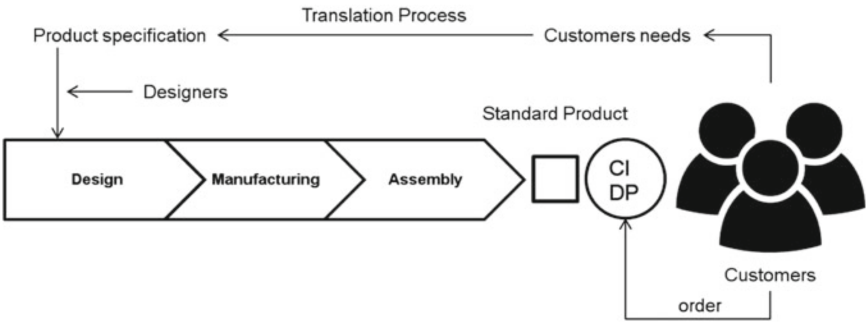
The application of GAs to the design of new products, requires two fundamental steps that will be further discussed in Sect. 5. First, we have to effectively encode the distinctive features of the product into a digital chromosome. The encoding can be simple in some cases, but in the general case this process is extremely complex. The availability of an effective encoding is the pre-requisite for the generation of the individuals. Secondly, we have to design a suitable fitness function capable to effectively select the individuals that will survive and will thus contribute to the evolution. Since a major goal of the design is the design of products that customers will appreciate, the fitness function of GENDE is a function of the appreciation of users for individuals (Takagi 2001). The more an individual, namely a product, is appreciated by users, the more that individual will score in the fitness function and consequently the more it will likely survive.

3 Related Work

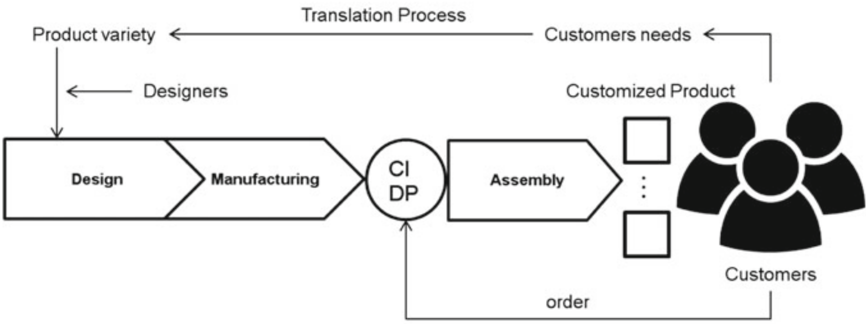
There are a number of papers in which GAs have been proposed to solve a number of design problems, such as the ones presented in Padhye (2012).

A more general product design problem (Rajeev and Ramesh 1987) has been studied in Sundar and Varghese (1996). In this paper, the problem is formulated within the conjoint analysis framework, in which users preferences on a limited number of product profiles are used to predict the valuation for any new product profile which was not initially evaluated. In realistic applications, the number of possible product profiles increases dramatically, and thus the authors propose the use of GAs to explore the product profiles search space. More recently, Vajna et al. proposed the Autogenetic Design Theory (Sndor et al. 2005). In this paper, a 3D parametric CAD is used to create the actual instance of a geometric model to be optimized by a set of parameters and a Finite Element Method (FEM) or a computational fluid dynamics system evaluates the actual instance. The optimization module performs changes on the geometric or topological parameters in order to fulfil the optimization aims. In Ho and Ming (2009) the authors use shape grammars, to express in a general form complex shapes, and GAs to develop stylistically consistent forms applied to the design of a camera. Kram/Weisshaars Breeding Tables project (Kram and Weisshaar 2003), is a renowned example of the employment of GAs to the product design. The algorithm takes in input constraints such as the size, weight, and tabletop height, then generates hundreds of configurations that are selected by the designers. Similarly, the Computational Chair project developed by EZCT Architecture and Design research (Hamda and Schoenauer 2004) uses a GA to generate design variations of a chair. While both these projects rely on GAs, they do not envision as in our case, the involvement of users in the implementation of the fitness function.

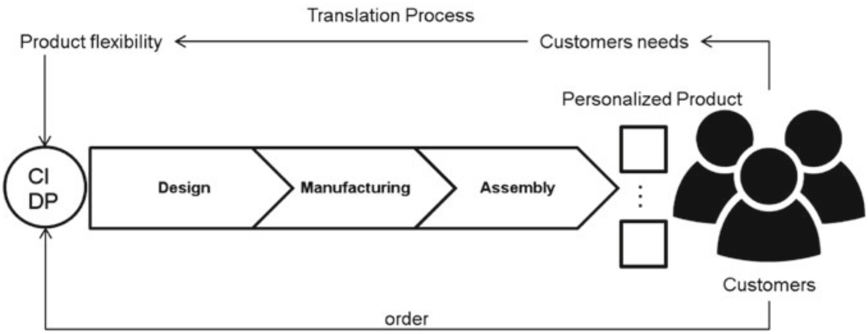
The involvement of users is explicitly considered in the interactive evolutionary computation (IEC) where the evolutionary computation optimizes systems based on subjective human evaluation (Takagi 2001). In Zhun et al. (2006) the authors explore the integration of human interaction with evolutionary design. In particular they claim that "*the fitness function should be able to take feedback from designers and customers constantly, enabling it to reflect changing market environments or user preferences*". However, they did not provide examples of such virtuous feedback loop. The work of Kelly and others (Kelly et al. 2011) presents an Interactive Evolutionary Systems (IES) that is used to identify the users' most preferred cola bottle shapes among a set of parametrized shapes. Most similar to our work, in Kim



(a) Customers have no additional chance to participate in value creation before the final product.



(b) Components are pre-designed and pre-produced according to forecast demands but customization is possible before assembly.



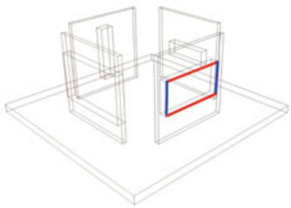
(c) CIDP is placed in the early stage of the value chain to provide customersa real individual customization and their participation since the design phase.

Fig. 3 Customer involvement decoupling point (CIDP) (Risdiyono and Pisut 2011) and Cho (2005); Hee-Su and Sung-Bae (1999), Kim explores the use of interactive genetic algorithms to the design of women's dress. In that paper, by incorporating the domain specific knowledge into the genotype, the author shows how to implement a more realistic design aid system.In that paper, by incorporating the domain specific knowledge into the genotype, the author shows how to implement a more realistic design aid system. However, these works, do not explicitly contemplate the involvement of users' communities as is nowadays possible with the pervasive adoption of on-line social networks.

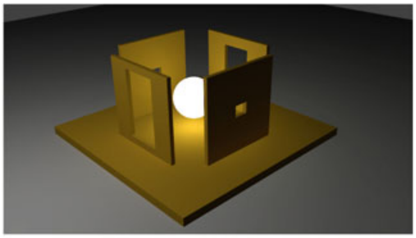
The physical form of a product is an unquestioned determinant of its marketplace success (Mitchell and Xuehong 1998) and this is the fundamental argument to support the interconnection of marketing and design, however their connections are not fully explored (Margaret and Lucy 2007). In Risdiyono and Pisut (2011) the authors explore the concept of design by customer: "*Design is a process of establishing the basic parameters of a product. From this perception, every customer can be considered as a designer*". Traditionally, the customer involvement decoupling point (CIDP), namely the point where customers are involved in value creation, is placed at the end of the process (see Fig. 3a). In such context, the process generates the same standard products for all the customers, and the hope is that the process in charge of translating customer needs into product specifications has been effective in providing good insights to the designers in order to achieve high customer satisfaction. In Fig. 3b, the CIDP is placed before the assembly process. Components are pre-designed and pre-produced according to forecast demands but in order to offer product variety, assembly process is postponed until customers complete their selection. Finally, in Fig. 3c a new CIDP is placed in the early stage of value chain to provide customers a real individual customization and support the design by customer (DBC) approach. In this perspective, GENDE can be considered among the first tool supporting the DBC approach.

4 Proof of Concept

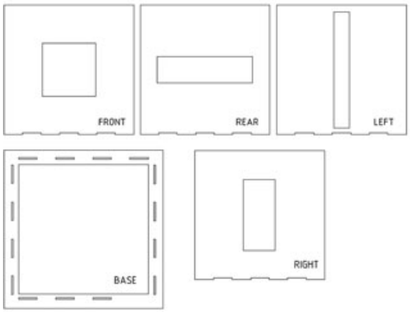
GENDE can be applied to the design a number of products in different areas, from fashion to furniture and jewelry, just to mention few of them. However in this paper we are more interested in testing the concept and the process that allows the involvement of users in the design process, rather then in the final outcome (i.e. the product). For this reason, to prove the concept of GENDE, we focused on the design of a simple desk lamp made of four rectangles panels with a hole in the middle (Figs. 4 and 5). The sizes of the holes is the result of the evolution implemented in GENDE. The GAs are implemented in the Python evolutionary computation framework DEAP (https://github.com/DEAP/deap). The population is made of 10 individuals (i.e. lamps), with $cxpb = 0.5$ (the probability of mating two individuals) and $mutpb = 0.2$ (the probability of mutating an individual). Each individual in the population is evaluated by 10 users and the fitness function for an individual is the sum of positive feedback received by that individual (i.e. the appreciation of the users). We stress that the pur-



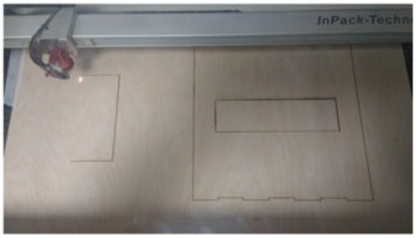
(a) The holes in the lamp are encoded in the chromosome and evolve.



(b) A render of an individual (i.e. a lamp) evaluated by users in the 3rd generation.



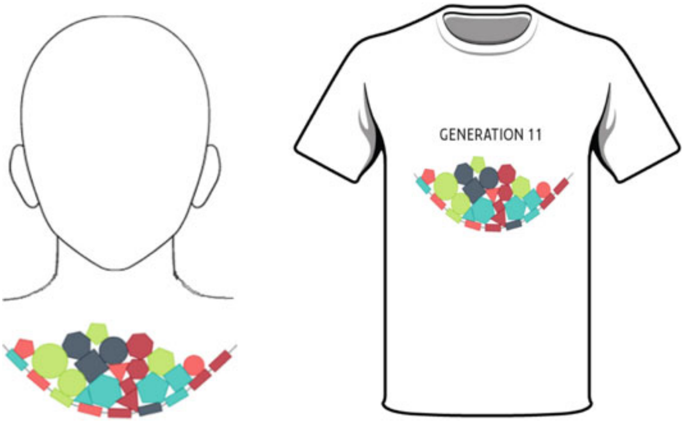
(c) The drawing for the lasercut.



(d) The lasercut of the parts.

Fig. 4 A lamp designed by GENDE

Fig. 5 The final product



(a) A GENDE necklace. (b) A t-shirt of an individual in genertaion 11.

Fig. 6 An example of GENDE applied to fashion accessories

pose of this initial experiment is to test the process, rather than the quality of the final outcome that necessarily requires the involvement of a larger number of users and a also a larger population of individuals.

Approaches similar to GENDE have been applied to the design of fashion clothes (Hee-Su and Sung-Bae 1999; Kim and Cho 2005). However, we do believe that fashion accessories, such as handbags, eyewear (see Fig. 2), jewelry and watches, might be more effectively designed by GENDE. In Fig. 6 we show an example of GENDE applied to the design of a necklace. The size, shape and color of the elements in the necklace evolve generation after generation according to users' feedback.

5 Discussion

In this paper we presented GENDE, a design tool based on Genetic Algorithms to support designers, but also common users, in the development of new products. Thanks to its unique participative design process, GENDE is not only a design support tool, but also a valuable marketing tool that brings the Customer Involvement Decoupling Point (CIDP) (Risdiyono and Pisut 2011) in the early stage of the value chain. The Proof of concept presented in Sect. 4 shows that GENDE can be actually used to design simple new products. However, to successfully apply the envisioned process to the design of more complex and general products, we still have to face a number of challenges, some of which are briefly discussed in the following.

The digital chromosome of complex products. When simple shapes are considered, the encoding of the distinguish features of a product into the digital chromosome is relatively simple. However, if the considered product is made of complex and interconnected shapes, their encoding can be difficult and it can lead to very long chromosomes that possibly make the application of GAs challenging both in terms of effectiveness (i.e. converge towards "good" solutions) and efficiency (i.e. converge in relatively small time).

Fitness function and user involvement. The fitness function selects the "best" individuals in a population. If the objective function is clear, objective and well defined (e.g. maximize the size of a shape) the application of GAs is straightforward. However, in our case, we aim at evaluating the appreciation of the users for a product. To this purpose, we use a feedback mechanism based on crowdsourcing; the current generation of products is shown to the users that can simply select via a Web and mobile App, the products they like more. To do not annoy users, only a limited number of products should be shown to each user; the system take care of getting the same number of feedbacks for each individual in the population. An exciting perspective to improve the effectiveness and efficiency of users' evaluation is the employment of neuromarketing techniques (Dan and Gregory 2010), in which users' appreciation can be evaluated analyzing the output of a Brain Computer Interface (BCI).

The fitness function for a given product is evaluated as a weighted function of the positive feedback for that product. To get more significant results, a critical mass of users should be involved, in order to guarantee unbiased results and a relatively fast convergence towards a population of "good" candidate products. The methods envisioned to involve such critical mass of users are beyond the scope of this paper, but foreseen the adoption of social and online marketing strategies.

Design versus marketing. The unique process envisioned in GENDE, guarantees that the generated products are appreciated by users, however cannot not guarantee at all that those products are not ordinary in terms of design.

Citing Don Norman "*Homogenization is disturbing. It diminishes the richness of life, the importance of historical roots, ritual and custom. Cultural diversity is a powerful, positive influence and we, as responsible designers, should pay much attention to how people behave in their environments, supporting the richness of cultural diversity. It is not the product that is important: it is how it is used, in context.*"

In this perspective, GENDE is not only a participatory design tool capable to involve in the design process a mass of users, but also a marketing tool in which users can contribute bringing into the process their own unique needs, stories and backgrounds. It is then again in the responsibility of the designers the possible interpretation of such contribution in the most creative and innovative way, with the purpose of realizing unique products.

Acknowledgements The author wish to thank the FABLAB ROMA http://www.laziofablab.it/, Via Casilina 3/T, 00182 Roma, for their kind support in the production of the prototype in Fig. 5.

References

Ariely D, Berns GS (2010) Neuromarketing: the hope and hype of neuroimaging in business. Nat Rev Neurosci 11(4):284–292

Balakrishnan PVS, Jacob VS (1996) Genetic algorithms for product design. Manage Sci 42(8):1105–1117

Bruce M, Daly L (2007) Design and marketing connections: creating added value. J Mark Manage 23(9–10):929–953

Fan Z, Andreasen M, Wang J, Goodman E, Hein L (2006) Towards an evolvable engineering design framework for interactive computer design support of mechatronic systems. In: Proceedings of the 2006 conference on integrated intelligent systems for engineering design, Amsterdam, The Netherlands. IOS Press, pp. 182–198

Genetic music project (2016). http://www.geneticmusicproject.com/. Accessed 13 July 2016

Grow your own picture: genetic algorithms and generative art (2016). http://chriscummins.cc/s/genetics/. Accessed 13 July 2016

Hamda H, Schoenauer M (2004) Studies on optimization: computational chair design using genetic algorithms. EZCT Architect Des Res

Hartmut B, Benedikt G, Julia L, Lazzeroni C (2012) Visualize, program, and create with processing. Generative design. Princeton Architectural Press

Kelly JC, Wakefield GH, Papalambros PY (2011) Evidence for using interactive genetic algorithms in shape preference assessment. Int J Prod Dev 13(2):168–184

Kim H-S, Cho S-B (1999) Development of an iga-based fashion design aid system with domain specific knowledge. In: 1999 IEEE international conference on systems, man, and cybernetics, 1999. IEEE SMC '99 conference proceedings, vol 3, pp 663–668

Kim H-S, Cho S-B (2005) Fashion design using interactive genetic algorithm with knowledge-based encoding. Springer, Berlin, pp 411–434

Kohli R, Krishnamurti R (1987) A heuristic approach to product design. Manage Sci 33(12):1523–1533

Kram R, Weisshaar C (2003) Breeding tables. http://www.kramweisshaar.com/projects/breedingtables.html

Lee HC, Tang MX (2009) Evolving product form designs using parametric shape grammars integrated with genetic programming. Artif Intell Eng Des Anal Manuf 23:131–158

Mitchell M (1998) An Introduction To Genetic Algorithms. MIT Press, Cambridge

Padhye N (2012) Evolutionary approaches for real world applications in 21st century. In: Proceedings of the 14th annual conference companion on genetic and evolutionary computation, GECCO '12, New York, NY, USA, 2012. ACM, pp 43–48

Risdiyono, Koomsap P (2011) Design by customer: concept and applications. J Intell Manuf (2011) Design by customer: concept and applications. 24(2):295–311

Takagi H (2001) Interactive evolutionary computation: fusion of the capabilities of ec optimization and human evaluation. Proc IEEE 89(9):1275–1296

Tedeschi A (2014) AAD algorithms aided design. Parametric strategies using grasshopper. Le Penseur

Tseng MM, Xuehong Du (1998) Design by customers for mass customization products. CIRP Ann Manuf Technol 47(1):103–106

Vajna S, Clement S, Jordan A, Bercsey T (2005) The autogenetic design theory: an evolutionary view of the design process. J Eng Des 16(4):423–440